

WE CLAIM:

1. A method for discriminating noise from signal in a noise-contaminated signal, comprising:

decomposing a frame of the noise-contaminated signal received in a predefined time period into decorrelated signal components;

recursively updating respective parameters characterizing a Gaussian noise distribution and a signal distribution of each of the respective components as a function of time; and

using the respective parameters to evaluate a composite Gaussian and signal distribution function to provide a measure of noise and signal contributions to the component.
2. The method as claimed in claim 1 wherein the signal is a noise-contaminated voice signal and recursively updating comprises recursively updating respective parameters characterizing the Gaussian noise distribution and a Laplacian voice distribution.
3. The method as claimed in claim 1 wherein decomposing the frame comprises applying a matrix transform to the frame, which consists of a predefined number of samples.
4. The method as claimed in claim 3 wherein applying the matrix transform comprises mapping the frame of samples from a time domain to a frequency domain.

5. The method as claimed in claim 4 wherein mapping the frame comprises applying a discrete cosine transform to the frame of samples.
6. The method as claimed in claim 3 wherein applying the matrix transform comprises mapping the frame of samples to basis functions, which are the components.
7. The method as claimed in claim 6 wherein mapping the frame comprises decomposing the frame into at least one of wavelets and sinusoidal functions.
8. The method as claimed in claim 6 further comprising recomputing the basis functions to adaptively optimize decomposition.
9. The method as claimed in claim 8 wherein applying the matrix transform comprises applying an adaptive Karhunen-Loeve transform.
10. The method as claimed in claim 2 wherein recursively updating comprises using a value computed when the components of a previous frame were processed to determine which of the parameters characterizing the respective distribution to update.
11. The method as claimed in claim 10 wherein the previously computed value is an *a priori* probability of the frame constituting noise, and using the *a priori* probability to determine which of the parameters to update comprises:

selecting a measure of variance that characterizes the Gaussian noise distribution if the *a priori*

probability is below a predetermined threshold;
and

otherwise selecting a measure of variance factor that
characterizes the Laplacian distribution.

12. The method as claimed in claim 11 wherein the a *priori* probability is defined by evaluating a hidden state of a hidden Markov model.
13. The method as claimed in claim 12 wherein recursively updating a parameter further comprises incrementally changing the parameter in accordance with a difference between an expected value of the component given the past value of the parameter, and the value of the component received.
14. The method as claimed in claim 13 wherein incrementally changing comprises applying a first order smoothing filter to the components.
15. The method as claimed in claim 14 wherein a time constant of the first order smoothing filter is chosen as a time during which the distribution is stationary.
16. The method as claimed in claim 11 wherein using the respective parameters to determine which of the parameters to update comprises computing a measure of fit of the components to a composite Gaussian and Laplacian distribution.
17. The method as claimed in claim 16 wherein using the respective parameters to determine which of the parameters to update further comprises:

computing a measure of fit of each of the received components to a respective Gaussian noise distribution defined using the respective parameters; and

comparing a mean of the measures of fit to the respective Gaussian noise distributions with a mean of the measures of fit to the composite Gaussian and Laplacian distributions, to compute a likelihood that the components of the frame constitute noise or noise-contaminated voice signal.

18. The method as claimed in claim 17 wherein computing a measure of fit to either of the distributions comprises evaluating the distribution at the value of the component received.
19. The method as claimed in claim 18 wherein comparing a mean of the measures of fit comprises dividing a product of the measures of fit of the components to the composite Gaussian and Laplacian distribution by a product of the measures of fit of the components to the noise distribution.
20. The method as claimed in claim 19 wherein using the respective parameters to evaluate further comprises using the likelihood and the *a priori* probability to compute an *a posteriori* probability that the frame is noise-contaminated voice signal.
21. The method as claimed in claim 20 wherein using the respective parameters to evaluate further comprises using the *a posteriori* probability and a predefined

fixed set of transition probabilities to compute an *a priori* probability that a next frame constitutes noise-contaminated voice signal.

22. The method as claimed in claim 1 wherein using the parameters to evaluate comprises computing at least an approximation to an expected value of the composite Gaussian and signal distribution using the value of the component, and the parameters, to obtain a signal-enhanced component, if it is determined that the frame is signal active.
23. The method as claimed in claim 22 wherein computing at least an approximation comprises computing a piece-wise linear function approximation of the expected value as a function of the parameters and the component.
24. Apparatus for speech enhancement, comprising:
 - a signal transformer for decomposing a frame of samples of a noise-contaminated speech signal received in a predetermined time interval into decorrelated signal components;
 - a component distribution parameter reviser for recursively updating respective parameters characterizing a Gaussian noise distribution and a Laplacian speech distribution of each of the respective components as a function of time;
 - a voice activity detector for determining whether the noise-contaminated speech signal is voice active in the time interval; and

a clean speech estimator for using composite Gaussian and Laplacian distributions defined with the parameters, and the values of the components to obtain a vector of speech-enhanced components, if it is determined by the voice activity detector that the frame is voice active; and

an inverse signal transform for re-composing the frame of samples.

25. The apparatus as claimed in claim 24 wherein the clean speech estimator computes an expected value of each of the composite Gaussian and Laplacian distributions to independently derive a speech-enhanced component corresponding to each of the components.
26. The apparatus as claimed in claim 25 wherein the signal transform comprises means for decomposing the frame of samples using a discrete cosine transform.